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Plume Detection

Bernd R. Schlei (T-1) and Lakshman Prasad (NIS-7)

Constrained Delaunay triangulations of the interiors of ultra-complex shapes such as clouds and trees may be used to provide a robust and simple quantitative characterization of these shapes. The morphological taxonomy of triangles into Junction, Sleeve, and Terminal triangles in the constrained Delaunay triangulation of a shape [1, 2, 3] enables the structural classification of ultra-complex shapes based on the relative statistical abundance of these triangle types [4, 5].

Specifically, such a statistical measure of the structural quality of ultra-complex shapes has been successfully used to address the problem of plume detection in hyperspectral imagery. This problem is of importance to satellite-based atmospheric imaging, and the automatic detection and analysis of industrial and other effluents for presence of suspect chemicals. In the case of plumes, most of the area of the plume shape is occupied by Junction triangles [4, 5]. This property of "plume-likeness" distinguishes plumes from other objects in imagery.

We have implemented an efficient application, wherein a nearly VGA resolution image is spectrally segmented and the emergent shapes in the segmentation are subjected to triangulation and subsequent analysis for plume-likeness.

Figure 1 shows a matched filter output of a broadband HIRIS LWIR image revealing an ammonia plume. The absorption tail is shown in white, and the emission tail is black. Figure 2 shows a spectral segmentation of Figure 1 into a binary image. Notice the presence of ambient noise. Figure 3 is a plot of the relative fraction of area covered by junction tri-

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angles in the constrained Delaunay triangulation of each "object" in Figure 2, against the object number. Objects whose area fraction occupied by junction triangles is two standard deviations above the mean are selected to be plume-like. Figure 4 depicts the fragments of the absorption plume identified as being plume-like; these are precisely the four

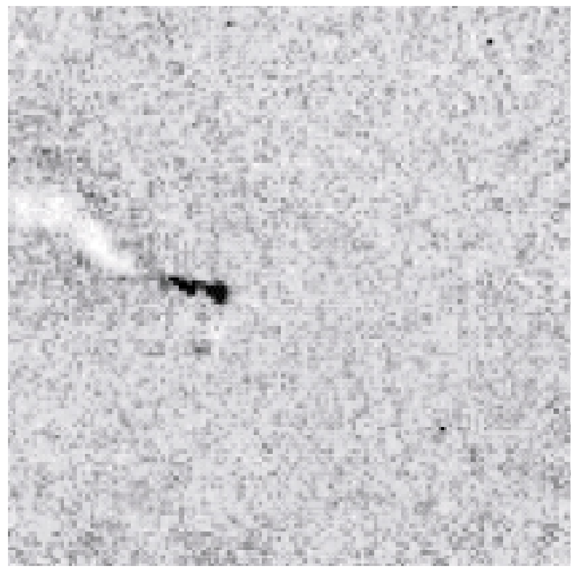

Figure 1: Matched filter output of broadband HIRIS LWIR image revealing NH_3 plume.

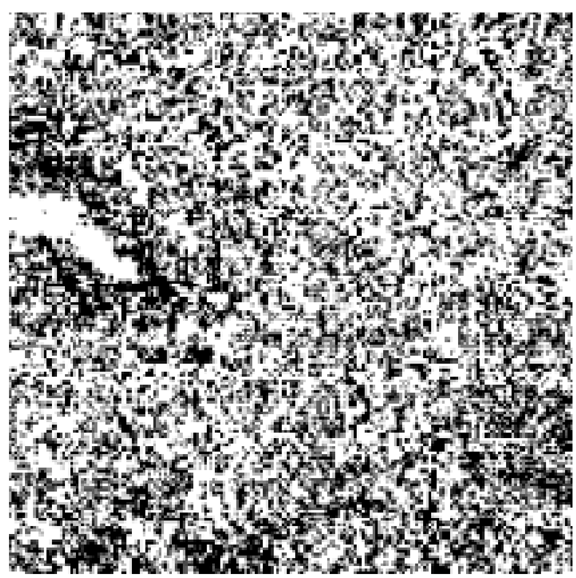

Figure 2: Wavelet-based spectral segmentation of the previous image.

objects whose relative fraction of area occupied by junction triangles is two standard deviations above the mean. Similarly, in a complementary segmentation, the emission tail is picked up as a plume-like object, although not so strongly because of the poor resolution of the image not revealing the plume-like structure clearly. Our implementation worked well, in the presence of a lot of noise, and rapidly (~ 10 seconds total processing time on a 400-MHz Intel Pentium IIPC with a LINUX OS), in the presence of nearly 6000 objects to be analyzed.

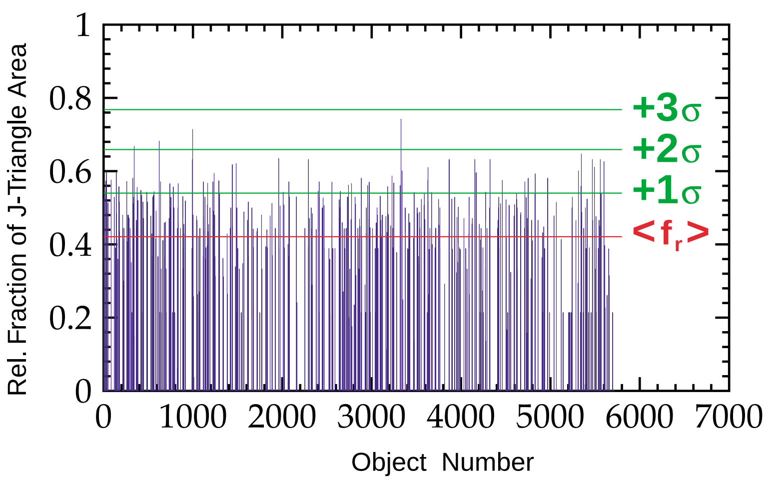

Figure 3: Measure of "plume-likeness" as a fraction of area occupied by Junction Delaunay triangles.

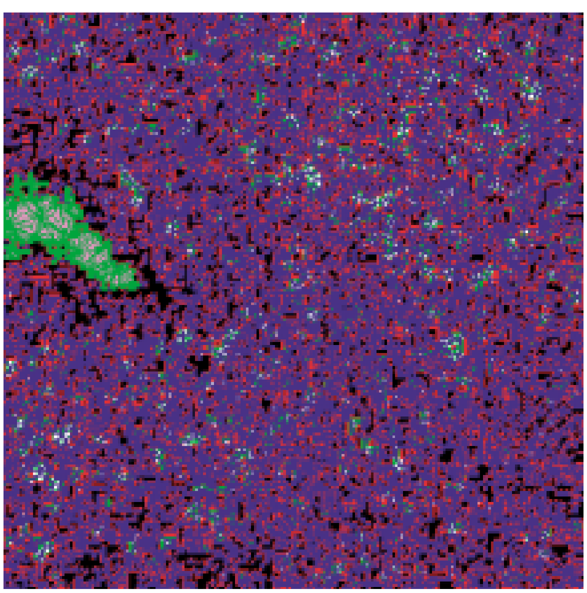

Figure 4: Isolation of plume-like features. Note the identification of the absorption tail of the NH_3 plume.

[1] L. Prasad, "Morphological Analysis of Shapes," *CNLS Newsletter*, No. 139, July '97, LALP-97-010-139, Center for Nonlinear Studies, Los Alamos National Laboratory.

[2] L. Prasad, R. Rao, "Morphological Analysis of Shapes," in *Special Feature, Supplement to the T-Division Self-Assessment for 1997/1998*, Los Alamos, May 1998, LA-UR-98-1150, p. 107.

[3] L. Prasad, R. L. Rao, "A geometric transform for shape feature extraction," Proceedings of SPIE's 45th Annual Meeting, San Diego, CA, Vol. 4117 (2000) 222.

[4] L. Prasad et al., "Perceptual Geometry and Image Understanding," LA-UR-01-0728, Laboratory Science Day presentation, 02/13/01, LANL, Los Alamos, NM.

[5] L. Prasad, R. L. Rao, B. R. Schlei, "Characterizing Ultra-complex Objects, The case of plume detection," to be presented at the IEEE Conference on Computer Vision and Pattern Recognition, Dec 11-13, 2001, Kauai, Hawaii, U.S.A.

http://www.nis.lanl.gov/~bschlei/labvis/

schlei@lanl.gov

prasad@lanl.gov

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